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FACTORS AFFECTING THE USE OF EXPANDED POLYSTYRENE (EPS) FOR SUSTAINABLE HOUSING CONSTRUCTION IN NIGERIA

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The goal of sustainable construction has always been underpinned by producing buildings with materials that are economically, socially and environmentally efficient. Over the years, the quest to achieving such goal has driven the use of different materials such as Expanded Polystyrene (EPS). While matters on housing construction is a topical issue in Abuja in particular and Nigeria in general, efforts on alternative construction methods to the conventional have been propagated particularly in the use of sustainable construction materials especially those materials proven to foster sustainable construction in other parts of the world. As a quest to bridge such ongoing efforts, this study investigates the factors affecting the use of EPS as a sustainable construction material with particular reference to its use in housing construction. The study identified Citec Estate, Mbora as a housing project in Abuja Nigeria that used EPS. Using purposive sampling, a total of 39 questionnaires were distributed to the professionals of Citec construction limited that were involved in the construction of Citec Estate Mbora project that used EPS. The Relative Importance Index (RII) is used to Rank the factors affecting the use of EPS. Among the 9 factors of EPS studied, while the re-usability potential of EPS ranked highest, its resistance to sound ranked lowest. The study reveals that EPS is perceived to exhibit better use for hot weather resistance than cold weather resistance. This finding indicates the probable sustainability in the use of EPS primarily because Abuja is considered a temperate climate. Furthermore, findings from this study reveal that 'economic factors' ranked higher than 'functional performance factors' in using EPS as a sustainable construction material. This study informs that although the use of EPS relative to its performance to fire and sound insulation needs to be improved, EPS has potential benefits to be used as a sustainable construction material for housing construction in Nigeria and other developed countries towards achieving sustainable housing needs.

Keywords: Expanded Polystyrene (EPS) , housing, Nigeria, sustainable construction

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INTRODUCTION

Over the years, the provision of available, affordable and accessible housing remains a challenge both in Nigeria and other developing countries. This has necessitated researches to investigate not only the underlying causes (with their corresponding effects) of the challenges towards providing affordable housing, but also remedies that could optimize these challenges. Regards the causes of this challenge, Ngugi, Kaluli, & Gairy (2017) and also Kageni (2014) attributes cost of construction materials, rising population, low income among other factors. Similarly, Ede, Alegiuno, & Aawoyera (2014) identified factors causing challenges to the provision of housing to include: rural-urban drift, general increase in living cost, high cost of urban land and the consequent high cost of housing scheme, the presence of excessive demands and dearth of housing facilities. Although it is evident underlying factors driving challenges faced in housing differ, there is unanimous agreement that optimizing each factor largely depends on sustainable construction practices.

According to (Practical Recommendations for Sustainable Construction PRESCO 2018), although defining the term ‘sustainable construction’ leads to never ending discussion based on its coverage of wide range of issues, the term ‘sustainable construction’ basically covers the expression of sustainable development principles in the construction sector. The most broad sustainable development principle is the Sustainable Development Goal (SDG). In a bid to optimize the afore-presented challenges in housing construction thereby ensuring human settlement is sustainable, Goal 11 of the Sustainable Development Goal stresses on the provision of adequate, safe and affordable housing (SDG 2015). Based on these attributes characterising sustainable settlements, several researchers have suggested the use of numerous materials that fulfil these qualifying attributes among others. While there exists an array of sustainable building materials adaptable to countries, regions and location, Ibrahim, Bankole, Ma’aji, Ohize, & Abdul (2013), Ede et al. (2014) and also Ngugi et al. (2017) all approved Expanded Polyesterene (EPS) to being a building material suitable for the construction of affordable and sustainable housing in developing countries. EPS is a thermo- plastic material produced in a three stage processes namely pre-expansion, Intermediate maturing and Final Moulding (Ede et al., 2014; Ngugi et al., 2017). The end-product of EPS used in construction is a meshed panel moulded into different shapes and sizes.

The use of EPS is relatively new in construction as against its use in industrial packaging (Ngugi et al., 2017; Lakatos & Kalmár, 2013; Kageni, 2014). Factors characterizing the use of EPS according to Paolella & Grifoni (2013) are its availability, lightness, resistance, insulating properties, cheapness and simplicity in use. In construction, EPS is used in the construction of walls, roofs and floor slabs among other elements. Over the years of its usage, EPS have exhibited properties that makes it suitable for use as a building material. As Ngugi et al. (2017) indicated, EPS used in construction is characterized by: exhibiting lower construction costs for energy consumption and operations;, environmentally friendly; able to save natural resources; comfortable and healthy for their users; and flexibility of being manufactured in multitude shapes and for multiple applications. Similarly, Doroudiani & Omidian (2010) reported that the use of EPS in construction proffers low material usage and installation costs, good performance, resistance to biodegradation, resistance to moisture penetration and availability in a wide range of sizes and densities. Furthermore, EPS is cost effective for thermal and sound insulation (Kageni 2014).

Despite all the merits and advantages of the EPS building system, the application by developers in the Nigerian building industry is very limited. This is confirmed by Ede et al. (2014) where they attribute such to relatively scarce knowledge in the innovative methods of construction and poor access to the material. Furthermore, low level of awareness of the building professionals and the general public as well as its non- availability has hampered the diffusion of EPS in Nigeria. Irrespective of these claims however, the use of EPS in construction in Nigeria is gradually gaining prominence. For instance, the work of Ibrahim et al. (2013) assessed the properties of EPS used in building construction in Citec Mbora Mount Pleasant Estate in Mbora District Abuja relative to mechanical performance (compressive strength specifically). However, Briga-Sá et al. (2013), Ede et al. (2014), Ngugi et al. (2017), and also The Ministry of Housing and Urban Poverty Alleviation Government of India (2017) all recommend the assessment of EPS based on non-mechanical measures (such as performance perception). Hence, this work will assess the factors influencing the use of EPS relative to performance perception in Citec Mbora Mount Pleasant Estate in Mbora District Abuja.

EXPANDED POLYESTERENE AND ITS USE IN HOUSING CONSTRUCTION

Based on the needs to devising approaches in optimizing construction challenges, the use of EPS has been considered as an alternative material in housing construction. Although the use of EPS is relatively new in construction (as claimed by (Kageni, 2014 and also Ngugi et al., 2017), its use in industrial packaging has been much longer. EPS is a thermo- plastic material formed by union of so many beads of polystyrene produced during a modelling process with supply of heat as water steam until the full formation of the desired properties (Ede et al., 2014; Ngugi et al., 2017). EPS is produced in a three stage processes namely pre-expansion, intermediate maturing and final moulding. According to Kageni (2014), Ede et al. (2014) and also Ngugi et al. (2017), at pre-expansion stage, the raw material (the beads) are heated in special machines called pre-expanders with steam at temperatures of about 100°C. During this process, the beads swell up to almost 50 times their original size and once the desired volume has been reached, the expanded beads are cooled, dried and then conveyed to storage silos for maturing. During the maturing stage, the expanded beads are stabilized in order to achieve a greater mechanical elasticity and improve expansion capacity. This process is carried out until equilibrium is reached. In the third processing stage, the beads are conveyed into moulds where they are further subjected to steam so that as the beads are compressed to bind together thereby forming a block "block moulding".

Although the afore-presented three stages are used in the production of EPS, it is worth mentioning that Ibrahim et al. (2013) and also Ngugi et al. (2017) further described that EPS used in design and construction of buildings must have steel mesh reinforcement embedded in it. Specific to housing construction, EPS has been reported by several authors to be used for wall panel, floor slabs and roof among other building elements as depicted in Table 1.

Table 1: Building elements made with EPS

S/No	Element	Authors
1	Wall	(Daouas et al. 2009), (Paolella & Grifoni 2013), (Ede et al. 2014), (Ngugi et al. 2017)
2	Floor (lightweight)	(Paolella & Grifoni 2013), (Ede et al. 2014), (Ngugi et al. 2017)
3	Roof (insulation)	(Paolella & Grifoni 2013), (Ngugi et al. 2017)
4	Staircase	(Ibrahim et al. 2013), (Ministry of Housing and Urban Poverty Alleviation Government of India 2017)
5	Ceiling	(Paolella & Grifoni 2013), (Ngugi et al. 2017)

While the works of Kageni (2014) and also Ngugi et al. (2017) illustrates the use of EPS in housing construction in Kenya, the work of Daouas et al. (2009) discussed the use of EPS in Tunisia. Similarly Doroudiani & Omidian (2010) demonstrates the use of EPS in Canada. In Nigeria, the works of Ibrahim et al. (2013) and also Ede et al., (2014) equally dealt with the use of EPS as a material used in housing construction. Although these studies differ in scope, they all concluded that the use of EPS is indeed sustainable for housing construction.

FACTORS CHARACTERISING EXPANDED POLYSTYRENE AS A SUSTAINABLE MATERIAL

Global concerns on housing challenges is responsible for platforms such as Goal 11 of the SDG (2015) which stresses on the provision of adequate, safe and affordable housing. Alongside these, several researches have been conducted to ascertain the potentials of EPS as a sustainable material in housing construction. Findings from conducted researches have informed on its potentials to be used for sustainable housing construction. Table 2 depicts some of such potentials as reported by several authors whose researches cover varying scopes in studying EPS used in construction.

Table 2: Factors attributed to using EPS in construction

S/No	Factor	Authors
1	Reusability potential	(Briga-Sá et al. 2013), (Ede et al. 2014), (Ministry of Housing and Urban Poverty Alleviation Government of India 2017), (Ngugi et al. 2017)
2	Time savings	(Ede et al. 2014) (Ministry of Housing and Urban Poverty Alleviation Government of India 2017), (Ngugi et al. 2017)
3	Job opportunity	(Kageni 2014)
4	Aesthetics	(Ibrahim et al. 2013), (Ministry of Housing and Urban Poverty Alleviation Government of India 2017)
5	Hot weather resistance	(EUMEPS 2013), (Lakatos & Kalmár 2013), (Alam et al. 2013), (Briga-Sá et al. 2013)
6	Fire resistance	(EUMEPS 2013), (Alam et al. 2013), (Briga-Sá et al. 2013), (Ministry of Housing and Urban Poverty Alleviation Government of India 2017), (Ngugi et al. 2017)
7	Cold weather resistance	(Daouas et al. 2009), (Kageni 2014), (Raj et al. 2014), (Ngugi et al. 2017)
8	Strength and stability	(Ibrahim et al. 2013), (Raj et al. 2014), (Shi et al. 2016), (Binici et al. 2005) (Ede et al. 2014) (EUMEPS 2013) (Alam et al. 2013) (Kageni 2014) (Ministry of Housing and Urban Poverty Alleviation Government of India 2017), (Ngugi et al. 2017),
9	Resistance to impact of sound	(Raj et al. 2014)(Ngugi et al. 2017)(Briga-Sá et al. 2013)(Ministry of Housing and Urban Poverty Alleviation Government of India 2017)

Although there exist other factors asides these, only these factors will be covered in this study. These factors cover the properties of EPS categorised under the following: mechanical; thermal; physical; and economical.

CITEC ESTATE AND THE USE OF EXPANDED POLYSTYRENE

Citec Mbora Mount Pleasant Estates Mbora district of Abuja is a classic example of the use of EPS in housing construction. It is a proposed 3,000 unit mass housing estate where EPS is used in construction of the houses. Construction activities commenced in 2003 and are still ongoing. Within the estate is a workshop for the production of building elements using EPS. The polyesterene material, some elements produced using it are depicted in Figure 1.

Figure 1: EPS elements used at Citec Mbora Mount Pleasant Estate Abuja
Source: (Researchers, 2018)

Although the fabrication of EPS elements of variable size, shape or colour can be done off-site, their assmblying subsequent finishing is done on-site. Detailed procedure for the assemblage of EPS elements used in housing construction can be found in (Ministry of Housing and Urban Poverty Alleviation Government of India 2017).

METHODOLOGY

Ede et al. (2014) recommend using performance perception to assess the use of EPS. Based on the objective of this study, data is collected using a survey technique. The data collection instrument is a structured questionnaire whereby each question consists of a 5-point Likert-type response item categories as: Very Poor (1); Poor (2); Average (3); Good (4); and Very Good (5). This 5-point Likert-type response item is adopted from (Ishiyaku 2016) that recommend its use for performance perception of buildings.

Judgmental sampling is used in selecting the respondents. The choice of such non-probability sampling is informed by the claim of Fellows & Liu (2008) where they recommend its use when a researcher intends to use some informed judgement to determine the population and or sample of a study. Similarly, Saunders, Lewis, & Thornhill (2009) recommend judgemental sampling when a researcher wish to select respondents that are particularly informative in fulfilling the research objectives. Furthermore, Kumar (2011) recommend the use of judgemental sampling if a research seeks to use experts in a field of inquiry.

There are limited construction firms using EPS in Nigeria. This is confirmed by Ibrahim et al. (2013) and also Ede et al., (2014). By extension, there are limited professionals and construction workers that have experience using EPS to build. Therefore, based on the forgoing justification of using judgemental sampling in researches, the approach for selecting the respondents of this study involved identifying the construction firm that has requisite experience using EPS whereby Citec Construction Limited was identified to have constructed the mass housing units at Citec Estate Mount Pleasant, Mbora District Abuja using EPS. Furthermore, only the staff with experience of using EPS are selected for this study. Based on these, a total of 39 staff of Citec Construction Limited constitute the respondents of this study. It is worthy to state that these 39 staff have been involved in construction using EPS at different stages since the project of Citec Estate using EPS commenced in 2003 whereby thousands of housing units using EPS have been completed and occupied and others still under construction (as at the time of collecting data for this study).

Descriptive statistics is used to analyse the data collected for this study. While IBM SPSS Statistics 23 is used to compute the frequencies, MS Excel is used to compute the RII. The RII technique (being a non-parametric technique) is used for the purpose of determining how the factors affecting the use of EPS rank (the general suitability of this technique is informed from the works of Carifio & Perla, 2007; Holt, 2014; Bishop & Herron, 2015; and also Harpe, 2015). Specific to construction management researchers however, Aigbavboa, Liphadzi & Thwala (2014) and also (Sodangi et al. 2014) not only encouraged the use of RII in construction management researches, but also hold the opinion that the use of RII is suitable for analysing data consisting of Likert items (as used in this research).The RII is computed using the equation by Holt (2014) and also Muhwezi, Acai, & Otim (2014).

$$RII = \frac{1n1 + 2n2 + \ldots AnA}{AN} \qquad (0 \leq RII \leq 1)$$

Where:

n1, n2, ... , nA = number of respondents scoring response stem integers 1 to Amax, respectively.

A = largest integer on the response item (5 for this research)

N= total number of respondents

Additionally to the use of the RII technique in this study, frequencies will also be used to identify the deviations from the median of each factor affecting the use of EPS. The use of the 'median' as a basis for analysis of data consisting of Likert items is stressed by some authors particularly due to the fact of the 'ordinal' nature of the data (refer to Holt, 2014; Joshi, Kale, Chandel, & Pal, 2015; Bishop & Herron, 2015; Carifio & Perla, 2007; and Harpe, 2015).

RESULTS

All 39 questionnaires distributed were not only completely retrieved but all questions were answered. The experience of the respondents in the use of EPS is illustrated in Table 3. While 38.46 percent of the respondents attest to have used EPS in construction only, over 60 percent of the respondents have used EPS in both design and construction.

Table 3: Respondents experience in the use of EPS

Background	Number of respondents	Percentage
Design only	0	0
Construction only	15	38.46
Design and construction	24	61.54
Total	39	100

Eight factors (reported in Table 2) warranting the use of EPS in the construction of building elements of houses were studied. Based on the data fetched from the survey, Table 4 depicts the results of the RII, ranking of the factors and both the scores above and below the median (3).

Table 4: Evaluation of the factors affecting the use of EPS

Factor	Frequency of responses					Scores above median	Scores below median	RII	Rank
	1 VP	2 P	3 A	4 G	5 VG				
Reusability potential	0	0	0	1	38	39	0	0.99	1st
Time savings	0	0	0	10	29	39	0	0.95	2nd
Job opportunity	0	0	0	9	30	39	0	0.95	2nd
Aesthetically pleasing	0	0	0	17	21	38	0	0.91	3rd
Hot weather resistance	0	0	17	21	1	22	0	0.72	4th
Fire resistance	0	1	14	24	0	24	1	0.72	4th
Cold weather resistance	0	0	23	16	0	16	0	0.68	5th
Strength and stability	0	0	28	11	0	11	0	0.66	6th
Resistance to impact of sound	1	0	26	12	0	12	1	0.65	7th

Legend: 1- Very Poor, 2- Poor, 3- Average, 4- Good, 5- Very Good

Based on the results, the use of EPS rank 1st based on its potential for re-usability (RII, 0.99). Also, the use of EPS for its time savings and job opportunity jointly rank

2nd (RII, 0.95). Likewise, the use of EPS for its aesthetics purposes rank 3rd (RII, 0.91). Similarly, the use of EPS for its hot weather resistance and also fire resistance jointly rank 4th (RII, 0.72). Furthermore, the use of EPS for its cold weather resistance rank 5th (RII, 0.68). Also, while the use of EPS for its strength and stability rank 6th (RII, 0.66), its use for resistance to the impact of sound rank 7th (RII, 0.65).

Concurrent to the afore-presented results, Table 4 also show that EPS could be 'poor' to fire resistance and also 'very poor' to resisting to impact of sound. Likewise, the use of EPS for its reusability potential, time savings job opportunity and also aesthetics all recorded over 95 percent responses above the median. Furthermore, although the use of EPS for its hot weather resistance and also fire resistance had an equal rank (4th; RII, 0.72), its use for fire resistance recorded more responses above the median (about 62 percent as against about 56 percent) compared to its use for hot weather resistance. Similarly, the use of EPS for its cold weather resistance, strength and stability and also resistance to impact of sound all recorded less than 50 percent responses above the median.

FINDINGS AND CONCLUSION

Results from this study reveal that EPS is perceived to be of better use for hot weather resistance than for cold weather resistance. This finding is consistent with that of Ibrahim et al. (2013) and also Ede et al. (2014) regarding the commendable heat resistance of EPS in Abuja. This property is an indication of the probable sustainability in the use of EPS primarily considering the hot climatic condition particularly during the daytime. Also, the annual variation of temperature in Abuja is such that the hot weather lasts longer than the cold weather. This by extension could result to achieving efficient insulation and cooling depending on the variations in the climatic conditions.

Furthermore, this study reveals that since economic factors' (re-usability, time savings and job opportunity) rank higher (1st and 2nd) than 'functional performance factors' (aesthetics, hot weather resistance, fire resistance cold weather resistance strength and stability resistance to the impact of sound which rank 3rd to 7th), the use of EPS could bear economic benefits which is an indication for its passing for a sustainable building material. This findings support those of Ngugi et al. (2017) and also Ede et al. (2014) whereby the performance perception of reusability of EPS was higher than mechanical factors.

This study informs that although the use of EPS relative to its performance to fire and sound insulation needs to be improved, EPS has potential benefits to be used as a sustainable construction material for housing construction in Abuja.

LIMITATIONS AND RECOMMENDATIONS FOR FUTURE STUDY

The limitation of this study is the di limited construction firms using EPS in Nigeria in general but Abuja in particular. Therefore, in a bid to propagating its usage based on its sustainability potentials, conducting assessments based on comparing EPS with conventional materials will improve the appreciation of EPS used for sustainable housing construction in Nigeria. Since the views in this study are from professionals that participated in building Citec Mbora Mount Pleasant Estate, future studies could assess EPS specific to tenants occupying the houses in Citec Mbora Mount Pleasant Estate.

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Appendix A

(Questionnaire)

Kindly select the performance of Expanded Polyesterene (EPS) used in housing construction relative to the following factors	Very Poor (1)	Poor (2)	Average (3)	Good (4)	Very Good (5)
Cold weather resistance					
Hot weather resistance					
Fire resistance					
Resistance to impact of sound					
Aesthetically pleasing					
Strength and stability					
Reusability potential					
Time savings					
Job opportunity					